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Most Influential Literature in Spinal Tuberculosis: A Global Disease Without Global Evidence

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Abstract

Study Design: Bibliometric review of the literature.

Objective: This bibliometric analysis aims to give an overview of the most influential academic literature written on spinal tuberculosis.

Methods: All databases included in the Thomson Reuters Web of Knowledge were searched for the most influential publications in spinal tuberculosis. The most cited articles published between 1950 and 2015, with the main focus on orthopedic surgery, were identified using a multistep approach, and a total of 100 articles were included. The publications were then analyzed in this bibliometric analysis.

Results: The number of citations ranged from 243 to 36, with an average of 77.11. The articles were published in 34 different journals, and the studies were conducted in 20 different countries. The top 3 countries, India, the United States, and China, published a total of 51% (n = 51) of all articles. Low-burden countries produced 60% (n = 60) of all articles in our list. African centers produced only 4% (n = 4) of all included articles.

Conclusions: Indian and Chinese researchers dominate evidence in spinal tuberculosis. Other areas with high disease burden, such as Africa, do not feature. Most publications are retrospective studies with a low level of evidence.

Keywords

tuberculosis, spine, Potts, vertebra, bibliometric

Introduction

For the past 50 years, an increase in the incidence of tuberculosis (TB) has been reported globally,[1] but the disease is most common in in low- to middle-income countries.[2] Through immigration and increased mobility of travelers, TB remains a global challenge and is still the leading cause of death caused by a single pathogen.[2] Spinal disease is the most common form of skeletal TB,[3,4] and is one of the main pathologies seen in spinal and general orthopedic units in the developing world. Growing economies in countries like China and India have led to an increase in medical research, but most low-income countries cannot generate scientific evidence as resources are already stretched with clinical work.[5] Yet, especially for these countries, it is challenging to address the clinical burden of endemic diseases without indigenous evidence and solutions.

Bibliometric analysis can be used to analyze the influence of articles by quantitative appraisal of its impact[6] in TB research[7] as well as in spinal surgery.[8] The objective of this study is to identify the 100 most cited and therefore most influential articles on spinal TB.

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Methods

From all available journals of the Thomson Reuters Web of Knowledge, we selected the 100 most influential articles on spinal TB between 1950 and 2015 by means of a bibliometric analysis.

Inclusion Criteria

All articles with focus on the clinical course or treatment of spinal TB were included. "Spinal tuberculosis" was defined as an infection of the spine caused by *Mycobacterium tuberculosis*. The "spine" was defined as the cervical, lumbar, thoracic, and sacral vertebrae and all intervertebral discs. All age groups were included.

Exclusion Criteria

All articles not predominantly focusing on spinal TB were excluded. This was the case in articles on spinal infections caused by various pathogens with only a minority of TB infections. All studies with a nonorthopedic focus were also excluded, that is, an article on the mechanism of TB drugs. Articles focusing on the infection of the spinal cord were excluded.

Selection Process

The selection process was started using a topic and title search in the "all database" of the Thomson Reuters Web of Knowledge. Seven keywords were used: spinal, spine, vertebral, Potts, spondylodiscitis, tuberculosis, and spondylitis. An asterisk was used to extend the search. For example, vertebr* will search for vertebral and vertebrae. The operator "AND" was used to narrow the search; by using it, the results will contain all Boolean queries. For example, vertebr* AND tubercu* will contain both keywords, whereas vertebr* OR tubercu* will contain either vertebr* or tubercu*. The 150 most cited articles were then explored for more keywords. One additional keyword was added, resulting in a total of 8 keywords.

With these final 8 keywords, we conducted the literature search, again in the "all database" of the Thomson Reuters Web of Knowledge, which led to a result of 11 539 articles. The first 100 publications were chosen for further analysis based on the consecutive ranking of their citation rate.

For each study included, we extracted the following parameters: title, year of publication, total citations, citations in 2014, citation density (citation number divided by the article age), article age, journal, first author, senior author, geographic origin, institution, number of patients, and age group of patients (adult, children, or both).

In case of only a single author, the author was considered both first and senior author.

Table 1. Area of Research.

	Publications	
Area	N	%
Clinical course	30	30%
Clinical outcome	23	23%
Imaging	21	21%
Surgical technique	26	26%

Table 2. Type of Research.

	Publications	
Type	N	%
Literature review	15	15%
Prospective research	6	6%
Retrospective case series	60	60%
Retrospective cohort	10	10%
Randomized controlled trial	4	4%

Analysis

All articles were systematically analyzed for the following information: area of research, type of study, and level of evidence (LoE).

The level of evidence was established using the *Journal of Bone and Joint Surgery American Volume*[9] ranking, with level I being the strongest and level V being the weakest level of evidence. Articles were first divided into 4 categories: diagnostic, prognostic, therapeutic, and economic.

The area of research was also assigned according to the primary focus of the article and subdivided into 4 categories (Table 1). The same was done for study type, which we divided into 5 categories (Table 2).

We ranked all articles according to their total citation number, number 1 having the highest number of citations and number 100 having the lowest. In case of an equal number, the articles were ranked according to citations in 2014 and citation density respectively.

Results

The number of citations ranged from 36 to 243, with an average of 77.11. All articles were published between 1950 and 2015 in 34 different journals (Table 3). The research originated from 19 countries (Table 4). Most evidence was level IV.

All articles were published in the English language.

Top Ten (Table 5)

The citation number in our top 10 articles ranged from 137 to 243. The articles were published between 1956 and 1999 and had an average age of 28.3 years (CI). The top journals in our top 10 were *Spine* (n = 3; 30%) and *Journal of Bone and Joint Surgery, American Volume* (n = 3; 30%). Both A. R. Hodgson

Table 3. Publishing Journals.

Journal	Number of Publications (n)
Journal of Bone and Joint Surgery—British Volume	20
Spine	14
Journal of Bone and Joint Surgery—American Volume	9
Clinical Orthopaedics and Related research	8
American Journal of Roentgenology	4
International Orthopedics	4
British Journal of Surgery	3
Neurosurgery	3
Radiologic Clinics of North America	3
Acta Orthopaedica Scandinavica	2
European Spine journal	2
Journal of Neurosurgery	2
Journal of Spinal Disorders and Techniques	2
Medicine	2
Radiology	2
Spine Journal	2
Acta Radiologica	1
Annals of Rheumatic Diseases	1
Canadian Medical Association Journal	1
Chest Journal	1
Clinical Infectious Diseases	1
Clinical Radiology	1
Journal de Radiologie	1
Journal of Infection	1
The Journal of Rheumatology	1
The Journal of Spinal Cord Medicine	1
Neuroradiology	1
Neurosurgical Review	1
Orthopedic Clinics of North America	1
The Journal Paraplegia	1
Postgraduate Medical Journal	1
Skeletal Radiology	1
Tubercle and Lung Disease	1
Journal of Computer Assisted Tomography	1

Table 4. Geographic Origin.

	Publications	
Country	N	%
India	23	23%
United States of America	15	15%
China	13	13%
China (Hong Kong)	10	10%
Turkey	9	9%
South Korea	8	8%
Saudi Arabia	7	7%
United Kingdom	4	4%
France	3	3%
South Africa	3	3%
Taiwan	3	3%
Canada	2	2%
Germany	2	2%
Japan	2	2%
Ireland	1	1%
Italy	1	1%
Malaysia	1	1%
Nigeria	1	1%
Spain	1	1%
Switzerland	1	1%

Table 5. Top 10 Publications.

	Top 10 Publications	Percentage of Top 10
Top country	China (Hong Kong) (n = 2)	20%
	South Korea (n = 2)	20%
	United States of America (n = 2)	20%
Top journal	*Journal of Bone and Joint Surgery—American Volume* (n = 3)	30%
	Spine (n = 3)	30%
Top author	Hodgson, A. R. (n = 2)	20%
	Moon, M. S. (n = 2)	20%
Top level of evidence	Level IV (n = 5)	80%
Top study type	Retrospective (n = 7)	70%
Top study category	Therapeutic (n = 8)	80%
Top area of research	Surgical technique (n = 6)	60%
Age group	Adults and children (n = 7)	70%
Average citations	174.4 (137-243)	
Average citations 2014	7.6 (4-13)	
Average article age (years)	28.3 (17-60)	
Average density (n/year)	7.18 (3-55-12.15)	

and M. S. Moon have authored 2 articles (20%); all other authors in our top 10 are responsible for one publication. A total of 6 articles (60%) originate from 3 different countries: China (Hong Kong; n = 2; 20%), South Korea (n = 2; 20%), and the United States (n = 2; 20%). The remaining articles were from India, Japan, Spain, and Turkey (Table 4).

The most cited article was written by H. G. Watts et al in 1996, in *Journal of Bone and Joint Surgery, American Volume*, with 243 citations. It reviews the clinical course of spinal TB with a LoE III (Table 6).

Geographic Origin

A total of 20 different countries was identified, located in 4 different continents: North America, Europe, Africa, and Asia. The geographic origin responsible for most publications was India (n = 23; 23%), followed by the United States (n = 15; 15%) and China (n = 13; 13%). See Figure 1. Together these countries published a total of 51 articles (51%) of our selection. Of the 13 articles originating from China, 10 (17.92%) were from Hong Kong.

Asia published most articles with 57% (n = 57), followed by Europe (n = 22; 22%), North America (n = 17; 17%), and Africa (n = 4; 4%; Table 4).

Table 6. The Most Influential Publications: Total Citations (n), Citations in 2014 (n), Citation Density (Number/Year).

Rank	Title	Citations	Citations in 2014	Citation Density
1	Watts, H. G., & Lifeso, R. M. (1996). Tuberculosis of bones and joints. *Journal of Bone and Joint Surgery, American Volume*, 78(2), 288-298.	243	7	12.15
2	Hodgson, A. R., & Stock, F. E. (1956). Anterior spinal fusion a preliminary communication on the radical treatment of Pott's disease and Pott's paraplegia. *British Journal of Surgery*, 44(185), 266-275.	213	7	3.55
3	Hodgson, A. R., Stock, F. E., Fang, H. S., & Ong, G. B. (1960). Anterior spinal fusion. The operative approach and pathological findings in 412 patients with Pott's disease of the spine. *British Journal of Surgery*, 48 172-178.	208	9	3.71
4	Oga, M., Arizono, T., Takasita, M., & Sugioka, Y. (1993). Evaluation of the risk of instrumentation as a foreign-body in spinal tuberculosis—clinical and biologic study. *Spine*, 18(13), 1890-1894.	178	7	7.74
5	Moon, M. S. (1997). Spine update tuberculosis of the spine—controversies and a new challenge. *Spine*, 22(15), 1791-1797.	169	13	8.89
6	Moon, M. S., Woo, Y. K., Lee, K. S., Ha, K. Y., Kim, S. S., & Sun, D. H. (1995). Posterior instrumentation and anterior interbody fusion for tuberculous kyphosis of dorsal and lumbar spines. *Spine*, *20*(17), 1910-1916.	167	11	7.9
7	Colmenero, J. D., Jimenez-Mejias, M. E., Sanchez-Lora, F. J., Reguera, J. M., Palomino-Nicas, J., Martos, F., et al. (1997). Pyogenic, tuberculous, and brucellar vertebral osteomyelitis: a descriptive and comparative study of 219 cases. *Annals of the Rheumatic Diseases*, 56(12), 709-715.	148	9	7.79
8	Yilmaz, C., Selek, H. Y., Gurkan, I., Erdemli, B., & Korkusuz, Z. (1999). Anterior instrumentation for the treatment of spinal tuberculosis. *Journal of Bone and Joint Surgery, American Volume*, 81(9), 1261-1267.	144	4	8.47
9	Rajasekaran, S., & Soundarapandian, S. (1989). Progression of kyphosis in tuberculosis of the spine treated by anterior arthrodesis. *Journal of Bone and Joint Surgery, American Volume*, 71(9), 1314-1323.	137	5	5.07
10	Nussbaum, E. S., Rockswold, G. L., Bergman, T. A., Erickson, D. L., & Seljeskog, E. L. (1995). Spinal tuberculosis—a diagnostic and management challenge. *Journal of Neurosurgery*, 83(2), 243-247.	137	4	6.52
11	Perronne, C., Saba, J., Behloul, Z., Salmonceron, D., Leport, C., Vilde, J. L., et al. (1994). Pyogenic and tuberculous spondylodiskitis (vertebral osteomyelitis) in 80 adult patients. *Clinical Infectious Diseases*, 19(4), 746-750.	131	7	5.95
12	Lifeso, R. M., Weaver, P., & Harder, E. H. (1985). Tuberculous spondylitis in adults. *Journal of Bone and Joint Surgery, American Volume*, 67(9), 1405-1413.	131	5	4.23
13	Rezai, A. R., Lee, M., Cooper, P. R., Errico, T. J., & Koslow, M. (1995). Modern management of spinal tuberculosis. *Neurosurgery*, 36(1), 87-97.	122	2	5.81
14	Pertuiset, E., Beaudreuil, J., Liote, F., Horusitzky, A., Kemiche, F., Richette, P., et al. (1999). Spinal tuberculosis in adults—a study of 103 cases in a developed country, 1980-1994. *Medicine*, 78(5), 309-320.	120	4	7.06
15	Rath, S. A., Neff, U., Schneider, O., & Richter, H. P. (1996). Neurosurgical management of thoracic and lumbar vertebral osteomyelitis and discitis in adults: a review of 43 consecutive surgically treated patients. *Neurosurgery*, 38(5), 926-933.	119	8	5.95
16	Sharif, H. S., Aideyan, O. A., Clark, D. C., Madkour, M. M., Aabed, M. Y., Mattsson, T. A., et al. (1989). Brucellar and tuberculous spondylitis—comparative imaging features. *Radiology*, 171(2), 419-425.	112	5	4.15
17	Maiuri, F., Iaconetta, G., Gallicchio, B., Manto, A., & Briganti, F. (1997). Spondylodiscitis—clinical and magnetic resonance diagnosis. *Spine*, 22(15), 1741-1746.	111	4	5.84
18	Jain, A. K. (2010). Tuberculosis of the spine: a fresh look at an old disease. *Journal of Bone and Joint Surgery, British Volume*, 92(7), 905-913.	109	30	18.17
19	Desai, S. S. (1994). Early diagnosis of spinal tuberculosis by MRI. *Journal of Bone and Joint Surgery, British Volume*, 76(6), 863-869.	107	3	4.86
20	Konstam, P. G., & Blesovsky, A. (1962). Ambulant treatment of spinal tuberculosis. *British Journal of Surgery*, 50(219), 26.	104	0	1.93
21	Turgut, M. (2001). Spinal tuberculosis (Pott's disease): its clinical presentation, surgical management, and outcome. A survey study on 694 patients. *Neurosurgical Review*, 24(1), 8-13.	101	14	6.73
22	Gorse, G. J., Pais, M. J., Kusske, J. A., & Cesario, T. C. (1983). Tuberculous spondylitis—a report of 6 cases and a review of the literature. *Medicine*, 62(3), 178-193.	101	0	3.06
23	Tuli, S. M. (1975). Results of treatment of spinal tuberculosis by middle-path regime. *Journal of Bone and Joint Surgery, British Volume*, 57(1), 13-23.	100	5	2.44
24	Yao, D. C., & Sartoris, D. J. (1995). Musculoskeletal tuberculosis. *Radiologic Clinics of North America*, 33(4), 679-689.	99	2	4.71
25	Weaver, P., & Lifeso, R. M. (1984). The radiological-diagnosis of tuberculosis of the adult spine. *Skeletal Radiology*, 12(3), 178-186.	95	5	2.97

(continued)

Table 6. (continued)

Rank	Title	Citations	Citations in 2014	Citation Density
26	Davies, P. D. O., Humphries, M. J., Byfield, S. P., Nunn, A. J., Darbyshire, J. H., Citron, K. M., et al. (1984). Bone and joint tuberculosis—a survey of notifications in England and Wales. *Journal of Bone and Joint Surgery, British Volume*, 66(3), 326-330.	95	2	2.97
27	Rajasekaran, S., & Shanmugasundaram, T. K. (1987). Prediction of the angle of Gibbus deformity in tuberculosis of the spine. *Journal of Bone and Joint Surgery, American Volume*, 69(4), 503-509.	94	5	3.24
28	Bailey, H. L., Gabriel, M., Hodgson, A. R., & Shin, J. S. (1972). Tuberculosis of spine in children—operative findings and results in 100 consecutive patients treated by removal of lesion and anterior grafting. *Journal of Bone and Joint Surgery, American Volume*, 4(8), 1633-1657.	94	1	2.14
29	Smith, A. S., Weinstein, M. A., Mizushima, A., Coughlin, B., Hayden, S. P., Lakin, M. M., et al. (1989). MR imaging characteristics of tuberculous spondylitis vs vertebral osteomyelitis. *American Journal of Roentgenology*, 153(2), 399-405.	92	1	3.41
30	Guven, O., Kumano, K., Yalcin, S., Karahan, M., & Tsuji, S. (1994). A single-stage posterior approach and rigid fixation for preventing kyphosis in the treatment of spinal tuberculosis. *Spine*, 19(9), 1039-1043.	90	2	4.09
31	Hsu, L. C. S., & Leong, J. C. Y. (1984). Tuberculosis of the lower cervical-spine (C2 to C7)—a report on 40 cases. *Journal of Bone and Joint Surgery, British Volume*, 66(1), 1-5.	90	2	2.81
32	Fang, D., Leong, J. C. Y., & Fang, H. S. Y. (1983). Tuberculosis of the upper cervical-spine. *Journal of Bone and Joint Surgery, British Volume*, 65(1), 47-50.	90	0	2.73
33	Ahmadi, J., Bajaj, A., Destian, S., Segall, H. D., & Zee, C. S. (1993). Spinal tuberculosis—atypical observations at MR-imaging. *Radiology, 189*(2), 489-493.	80	4	3.52
34	Shanley, D. J. (1995). Tuberculosis of the spine—imaging features. *American Journal of Roentgenology*, 164(3), 659-664.	82	3	3.9
35	Jin, D. D., Qu, D. B., Chen, J. T., & Zhang, H. (2004). One-stage anterior interbody autografting and instrumentation in primary surgical management of thoracolumbar spinal tuberculosis. *European Spine Journal*, 13(2), 114-121.	80	6	6.67
36	Jain, R., Sawhney, S., & Berry, M. (1993). Computed-tomography of vertebral tuberculosis—patterns of bone destruction. *Clinical Radiology*, 47(3), 196-199.	78	6	3.39
37	Sundararaj, G. D., Behera, S., Ravi, V., Venkatesh, K., Cherian, V. M., & Lee, V. (2003). Role of posterior stabilisation in the management of tuberculosis of the dorsal and lumbar spine. *Journal of Bone and Joint Surgery, British Volume*, 85(1), 100-106.	78	5	6
38	Sharif, H. S., Morgan, J. L., Alshahed, M. S., & Althagafi, M. Y. A. (1995). Role of CT and MR-imaging in the management of tuberculous spondylitis. *Radiologic Clinics of North America*, 33(4), 787-804.	77	2	3.67
39	Moore, S. L., & Rafii, M. (2001). Imaging of musculoskeletal and spinal tuberculosis. *Radiologic Clinics of North America*, 39(2), 329.	75	4	5
40	Moon, M. S., Moon, Y. W., Moon, J. L., Kim, S. S., & Sun, D. H. (2002). Conservative treatment of tuberculosis of the lumbar and lumbosacral spine. *Clinical Orthopaedics and Related Research*, (398), 40-49.	75	3	5.36
41	Rajasekaran, S. (2001). The natural history of post-tubercular kyphosis in children—radiological signs which predict late increase in deformity. *Journal of Bone and Joint Surgery, British Volume*, 83(7), 954-962.	74	7	4.93
42	Mehta, J. S., & Bhojraj, S. Y. (2001). Tuberculosis of the thoracic spine—a classification based on the selection of surgical strategies. *Journal of Bone and Joint Surgery, British Volume*, 83(6), 859-863.	72	6	4.8
43	Yau, A. C. M. C., Hsu, L. C. S., Obrien, J. P., & Hodgson, A. R. (1974). Tuberculous kyphosis—correction with spinal osteotomy, halo-pelvic distraction, and anterior and posterior fusion. *Journal of Bone and Joint Surgery, American Volume*, 56(7), 1419-1434.	72	4	1.71
44	Lee, S., Sung, J., & Park, Y. (2006). Single-stage transpedicular decompression and posterior instrumentation in treatment of thoracic and thoracolumbar spinal tuberculosis—a retrospective case series. *Journal of Spinal Disorders & Techniques*, 19(8), 595-602.	71	11	7.1
45	Jung, N. Y., Jee, W. H., Ha, K. Y., Park, C. K., & Byun, J. Y. (2004). Discrimination of tuberculous spondylitis from pyogenic spondylitis on MRI. *American Journal of Roentgenology*, 182(6), 1405-1410.	71	9	5.92
46	Ozdemir, H. M., Us, A. K., & Ogun, T. (2003). The role of anterior spinal instrumentation and allograft fibula for the treatment of Pott disease. *Spine*, 28(5), 474-479.	70	3	5.38
47	Klockner, C., & Valencia, R. (2003). Sagittal alignment after anterior debridement and fusion with or without additional posterior instrumentation in the treatment of pyogenic and tuberculous spondylodiscitis. *Spine*, 28(10), 1036-1042.	68	7	5.23
48	Enarson, D. A., Fujii, M., Nakielna, E. M., & Grzybowski, S. (1979). Bone and joint tuberculosis—continuing problem. *Canadian Medical Association Journal*, 120(2), 139-145.	68	0	1.84

(continued)

Table 6. (continued)

Rank	Title	Citations	Citations in 2014	Citation Density
49	Talu, U., Gogus, A., Ozturk, C., Hamzaoglu, A., & Domanic, U. (2006). The role of posterior instrumentation and fusion after anterior radical debridement and fusion in the surgical treatment of spinal tuberculosis: experience of 127 cases. *Journal of Spinal Disorders & Techniques*, 19(8), 554-559.	68	10	6.8
50	BoachieAdjei, O., & Squillante, R. G. (1996). Tuberculosis of the spine. *Orthopedic Clinics of North America*, 27(1), 95.	67	3	3.35
51	Rajasekaran, S. (2002). The problem of deformity in spinal tuberculosis. *Clinical Orthopaedics and Related Research*, (398), 85-92.	66	6	4.71
52	Hoffman, E. B., Crosier, J. H., & Cremin, B. J. (1993). Imaging in children with spinal tuberculosis—a comparison of radiography, computed-tomography and magnetic-resonance-imaging. *Journal of Bone and Joint Surgery, British Volume*, 75(2), 233-239.	65	1	2.83
53	Rajasekaran, S., Shanmugasundaram, T. K., Prabhakar, R., Dheenadhayalan, J., Shetty, A. P., & Shetty, D. K. (1998). Tuberculous lesions of the lumbosacral region—a 15-year follow-up of patients treated by ambulant chemotherapy. *Spine*, 23(10), 1163-1167.	64	2	3.56
54	Louw, J. A. (1990). Spinal tuberculosis with neurological deficit—treatment with anterior vascularized rib grafts, posterior osteotomies and fusion. *Journal of Bone and Joint Surgery, British Volume*, 72(4), 686-693.	62	1	2.38
55	Tuli, S. M. (1995). Severe kyphotic deformity in tuberculosis of the spine. *International Orthopaedics*, 19(5), 327-331.	58	2	2.76
56	Jain, A. K. (2002). Treatment of tuberculosis of the spine with neurologic complications. *Clinical Orthopaedics and Related Research*, (398), 75-84.	57	7	4.07
57	Fukuta, S., Miyamoto, K., Masuda, T., Hosoe, H., Kodama, H., Nishimoto, H., et al. (2003). Two-stage (posterior and anterior) surgical treatment using posterior spinal instrumentation for pyogenic and tuberculotic spondylitis. *Spine*, 28(15), E302-E308.	54	10	4.15
58	Dai, L. Y., Jiang, L. S., Wang, W., & Cui, Y. M. (2005). Single-stage anterior autogenous bone grafting and instrumentation in the surgical management of spinal tuberculosis. *Spine*, 30(20), 2342-2349.	52	3	4.73
59	Jain, A. K., & Dhammi, I. K. (2007). Tuberculosis of the spine—a review. *Clinical Orthopaedics and Related Research*, (460), 39-49.	52	9	5.78
60	Turunc, T., Demiroglu, Y. Z., Uncu, H., Colakoglu, S., & Arslan, H. (2007). A comparative analysis of tuberculous, brucellar and pyogenic spontaneous spondylodiscitis patients. *Journal of Infection*, 55(2), 158-163.	52	7	5.78
61	Nene, A., & Bhojraj, S. (2005). Results of nonsurgical treatment of thoracic spinal tuberculosis in adults. The Spine Journal, 5(1), 79-84.	51	4	4.64
62	Schulitz, K. P., Kothe, R., Leong, J. C. Y., & Wehling, P. (1997). Growth changes of solidly fused kyphotic bloc after surgery for tuberculosis—comparison of four procedures. *Spine*, 22(10), 1150-1155.	51	4	2.68
63	Benli, I. T., Acaroglu, E., Akalin, S., Kis, M., Duman, E., & Un, A. (2003). Anterior radical debridement and anterior instrumentation in tuberculosis spondylitis. *European Spine Journal*, 12(2), 224-234.	51	3	3.92
64	Parthasarathy, R., Sriram, K., Santha, T., Prabhakar, R., Somasundaram, P. R., & Sivasubramanian, S. (1999). Short-course chemotherapy for tuberculosis of the spine—a comparison between ambulant treatment and radical surgery—ten-year report. *Journal of Bone and Joint Surgery, British Volume*, 81(3), 464-471.	50	5	2.94
65	Kim, N. H., Lee, H. M., & Suh, J. S. (1994). Magnetic-resonance-imaging for the diagnosis of tuberculous spondylitis. *Spine*, 19(21), 2451-2455.	50	1	2.27
66	Lee, T. C., Lu, K., Yang, L. C., Huang, H. Y., & Liang, C. L. (1999). Transpedicular instrumentation as an adjunct in the treatment of thoracolumbar and lumbar spine tuberculosis with early stage bone destruction. *Journal of Neurosurgery*, 91(2), 163-169.	49	3	2.88
67	Hsu, L. C. S., Cheng, C. L., & Leong, J. C. Y. (1988). Potts paraplegia of late onset—the cause of compression and results after anterior decompression. *Journal of Bone and Joint Surgery, British Volume*, 70(4), 534-538.	49	1	1.75
68	Janssens, J. P., & Dehaller, R. (1990). Spinal tuberculosis in a developed country—a review of 26 cases with special emphasis on abscesses and neurologic complications. *Clinical Orthopaedics and Related Research*, (257), 67-75.	49	0	1.88
69	Tuli, S. M. (2007). Tuberculosis of the spine—a historical review. *Clinical Orthopaedics and Related Research*, (460), 29-38.	48	11	5.33
70	Chen, W. J., Wu, C. C., Jung, C. H., Chen, L. H., Niu, C. C., & Lai, P. L. (2002). Combined anterior and posterior surgeries in the treatment of spinal tuberculous spondylitis. *Clinical Orthopaedics and Related Research*, (398), 50-59.	48	6	3.43

(continued)

Table 6. (continued)

Rank	Title	Citations	Citations in 2014	Citation Density
71	Lindahl, S., Nyman, R. S., Brismar, J., Hugosson, C., & Lundstedt, C. (1996). Imaging of tuberculosis. 4. Spinal manifestations in 63 patients. *Acta Radiologica*, 37(4), 506-511.	48	3	2.4
72	Lifeso, R. (1987). Atlantoaxial tuberculosis in adults. *Journal of Bone and Joint Surgery, British Volume*, 69(2), 183-187.	48	1	1.66
73	Babhulkar, S. S., Tayade, W. B., & Babhulkar, S. K. (1984). Atypical spinal tuberculosis. *Journal of Bone and Joint Surgery, British Volume*, 66(2), 239-242.	47	2	1.47
74	Chen, W. J., Chen, C. H., & Shih, C. H. (1995). Surgical-treatment of tuberculous spondylitis—50 patients followed for 2-8 years. *Acta Orthopaedica Scandinavica*, 66(2), 137-142.	47	0	2.24
75	Hodgson, A. R., Skinsnes, O. K., & Leong, C. Y. (1967). Pathogenesis of Potts paraplegia. *Journal of Bone and Joint Surgery, American Volume*, 49(6), 1147.	46	1	0.94
76	Whelan, M. A., Naidich, D. P., Post, J. D., & Chase, N. E. (1983). Computed-tomography of spinal tuberculosis. *Journal of Computer Assisted Tomography*, 7(1), 25-30.	46	0	1.39
77	Friedman, B. (1966). Chemotherapy of tuberculosis of spine. *Journal of Bone and Joint Surgery, American Volume*, 48(3), 451.	46	0	0.92
78	Dobson, J. (1951). Tuberculosis of the spine; an analysis of the results of conservative treatment and of the factors influencing the prognosis. *Journal of Bone and Joint Surgery, British Volume*, 33(4), 517-31.	46	0	0.71
79	Tuli, S. M. (2007). Tuberculosis of the spine—a historical review. *Clinical Orthopaedics and Related Research*, (460), 29-38.	44	2	0.9
80	Darbyshire, J. (1993). Controlled trial of short-course regimens of chemotherapy in the ambulatory treatment of spinal tuberculosis—results at 3 years of a study in Korea. *Journal of Bone and Joint Surgery, British Volume*, 75(2), 240-248.	44	1	1.91
81	Upadhyay, S. S., Saji, J., & Yau, A. C. M. C. (1996). Duration of antituberculosis chemotherapy in conjunction with radical surgery in the management of spinal tuberculosis. *Spine*, 21(16), 1898-1903.	43	1	2.15
82	Almulhim, F. A., Ibrahim, E. M., Elhassan, A. Y., & Moharram, H. M. (1995). Magnetic-resonance-imaging of tuberculous spondylitis. *Spine*, 20(21), 2287-2292.	43	1	2.01
83	Laberge, J. M., & Brantzawadzki, M. (1984). Evaluation of Potts disease with computed-tomography. *Neuroradiology*, 26(6), 429-434.	43	0	1.34
84	Oguz, E., Sehirlioglu, A., Altinmakas, M., Ozturk, C., Komurcu, M., Solakoglu, C., et al. (2008). A new classification and guide for surgical treatment of spinal tuberculosis. *International Orthopaedics*, 32(1), 127-133.	42	9	5.25
85	Behari, S., Nayak, S. R., Bhargava, V., Banerji, D., Chhabra, D. K., & Jain, V. K. (2003). Craniocervical tuberculosis: protocol of surgical management. *Neurosurgery*, 52(1), 72-80.	42	2	3.23
86	Garg, R. K., & Somvanshi, D. S. (2011). Spinal tuberculosis: a review. *Journal of Spinal Cord Medicine*, 34(5), 440-454.	41	12	8.2
87	Pattisson, P. R. M. (1986). Potts paraplegia—an account of the treatment of 89 consecutive patients. *Paraplegia*, 24(2), 77-91.	41	0	1.37
88	Jain, A. K., Dhammi, I. K., Prashad, B., Sinha, S., & Mishra, P. (2008). Simultaneous anterior decompression and posterior instrumentation of the tuberculous spine using an anterolateral extrapleural approach. *Journal of Bone and Joint Surgery, British Volume*, 90(11), 1477-1481.	40	5	5
89	Cormican, L., Hammal, R., Messenger, J., & Milburn, H. J. (2006). Current difficulties in the diagnosis and management of spinal tuberculosis. *Postgraduate Medical Journal*, 82(963), 46-51.	40	2	4
90	Leibert, E., Schluger, N. W., Bonk, S., & Rom, W. N. (1996). Spinal tuberculosis in patients with human immunodeficiency virus infection: clinical presentation, therapy and outcome. *Tubercle and Lung Disease*, 77(4), 329-334.	40	0	2
91	Martin, N. S. (1970). Tuberculosis of the spine. A study of the results of treatment during the last twenty-five years. *Journal of Bone and Joint Surgery, British Volume*, 52(4), 613-28.	40	0	0.87
92	Moorthy, S., & Prabhu, N. K. (2002). Spectrum of MR imaging findings in spinal tuberculosis. *American Journal of Roentgenology*, 179(4), 979-983.	39	3	2.79
93	Wang, Z., Ge, Z., Jin, W., Qiao, Y., Ding, H., Zhao, H., et al. (2007). Treatment of spinal tuberculosis with ultrashort-course chemotherapy in conjunction with partial excision of pathologic vertebrae. *Spine Journal*, 7(6), 671-681.	38	6	4.22
94	Govender, S. (2002). The outcome of allografts and anterior instrumentation in spinal tuberculosis. *Clinical Orthopaedics and Related Research*, (398), 60-66.	38	3	2.71
95	Griffiths, D. L., Seddon, H., Ball, P. J., Darbyshire, J., Fox, W., Kemp, H. B. S., et al. (1999). Five-year assessment of controlled trials of short-course chemotherapy regimens of 6, 9 or 18 months' duration for spinal tuberculosis in patients ambulatory from the start or undergoing radical surgery—fourteenth report of the medical research council working party on tuberculosis of the spine. *International Orthopaedics*, 23(2), 73-81.	38	2	2.24

(continued)

Table 6. (continued)

Rank	Title	Citations	Citations in 2014	Citation Density
96	Cotten, A., Flipo, R. M., Drouot, M. H., Maury, F., Chastanet, P., Duquesnoy, B., et al. (1996). Spinal tuberculosis: study of the radiological aspects of 82 cases. *Journal De Radiologie*, 77(6), 419-426.	38	1	1.9
97	Omari, B., Robertson, J. M., Nelson, R. J., & Chiu, L. C. (1989). Potts disease—a resurgent challenge to the thoracic surgeon. *Chest*, 95(1), 145-150.	38	1	1.41
98	Naim-ur-Rahman. (1980). Atypical forms of spinal tuberculosis. *Journal of Bone and Joint Surgery, British Volume*, 62(2), 162-165.	37	2	1.03
99	Fam, A. G., & Rubenstein, J. (1993). Another look at spinal tuberculosis. *Journal of Rheumatology*, 20(10), 1731-1740.	37	0	1.61
100	Moon, M. S., Moon, Y. W., Moon, J. L., Kim, S. S., & Sun, D. H. (2002). Conservative treatment of tuberculosis of the lumbar and lumbosacral spine. *Clinical Orthopaedics and Related Research*, (398), 40-49.	36	0	1.24

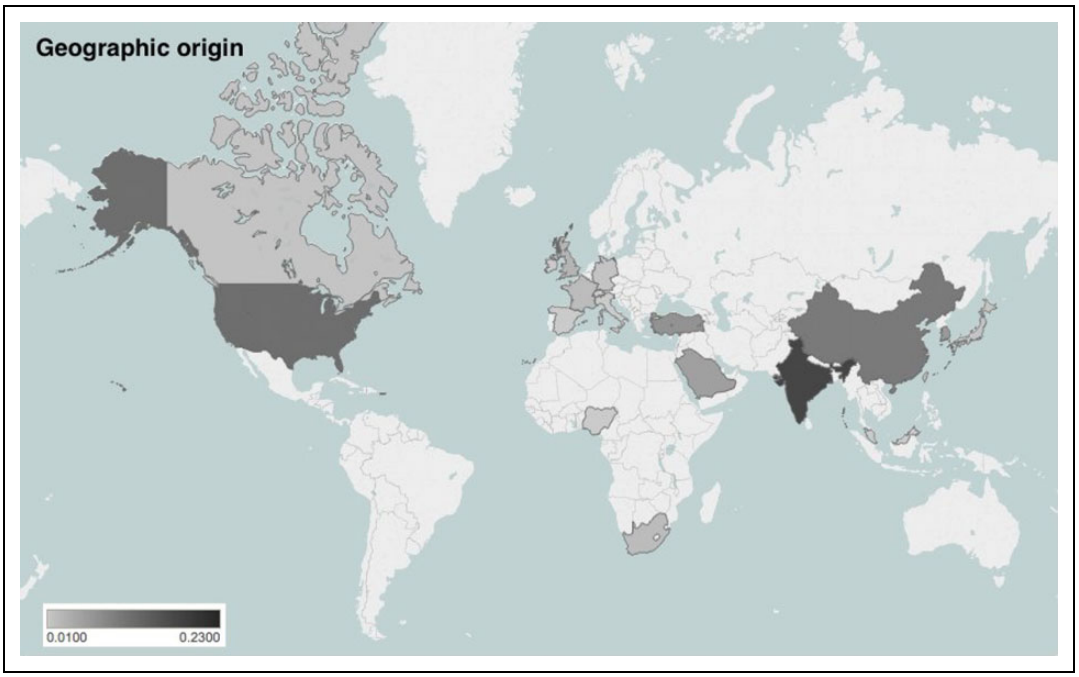

Figure 1. Geographic origin. Countries are highlighted with light gray (least publications) to dark gray (most publications).

Journals

Most articles were published by *Journal of Bone and Joint Surgery, British Volume*, with 20 publications (20%), followed by *Spine* (n = 14; 14%), *Journal of Bone and Joint Surgery, American Volume* (n = 9; 9%), *Clinical Orthopaedics and Related Research* (n = 8; 8%), and *American Journal of Roentgenology* (n = 4; 4%). These 5 of the 34 journals in our selection produced 55% (n = 55) of the included articles.

Authorship

A total of 11 authors in our list published 2 or more articles. S. Rajasekaran, from India, is the most published author with a total of 5 publications (5%), 5 as first author and 2 as first or senior author. S. M. Tuli has published most articles (n = 3; 3%) as senior author and was listed as the second most published author (Table 7).

Article Age

The oldest article included in our list was published in 1951 and written by J. Dobson. It was cited 46 times and has a citation density of 0.71, with zero citations in 2014. The most recent article included, published in 2011, is by R. K. Garg et al, with a citation number of 41 and a citation density of 8.20.

Most articles were published between 1990 and 2000 (n = 38; 38%), and a total of 32 articles (32%) were published before 1990.

Table 7. Authorship.

First Author	Total Publications (n)	First Author (n)	Senior Author (n)
Rajasekaran, S.	5	5	2
Tuli, S. M.	4	4	3
Jain, A. K.	4	4	2
Lifeso, R. M.	4	2	2
Moon, M. S.	4	4	1
Hodgson, A. R.	4	3	1
Leong, C. Y.	3	0	3
Chen, W. J.	2	2	0
Hsu, L. C. S.	2	2	0
Sharif, H. S.	2	2	0
Sun, D. H.	2	0	2

Level of Evidence

Our top 10 consists of only level III evidence (n = 5; 50%) and level IV evidence (n = 5; 50%). Only 4% (n = 4) of our list were Level I studies. The large majority (n = 50; 50%) of all studies was assigned a level IV or lower. Rajasekaran of India published 2 articles with level I evidence. Of the 4 articles, 3 originated from India and 1 article is from the United Kingdom. Their area of research varied from clinical course (n = 2), imaging (n = 1), and surgical technique (n = 1). Most of the remaining articles were level IV evidence (n = 42).

The distribution of area of research and study type of all included articles can be found in Tables 1 and 2.

Discussion

Article age

The oldest article in our list was published 65 years ago, written by J. Dobson. It is ranked 75 in our list with 46 citations and might be outdated when compared to the mean age of all articles of 23.2 years. This is supported by the fact that it has not received citations in 2014.

Most articles were published between 1980 and 1990 (n = 56; 56%). The 5 oldest publications are all published before 1997 but are still of significance in current literature. Of these articles, 3 have received more than 100 citations and 2 are in our top 10, both written by A. R. Hodgson et al in places 2 and 3.

Geographic Origin and Journals

Most publications (n = 23; 23%) in our list are from India, a country listed by the World Health Organization (WHO) as a high-burden country in the incidence and prevalence of TB as well as multidrug resistance TB and TB-HIV coinfection. India is followed by the United States, responsible for 15 articles (15%; Figure 1). Although the United States faces severe TB outbreaks,[10] it is not listed as a high-burden country by the WHO (Figure 2). China is among the top 3 countries with 13 publications (13%). Hong Kong published 10 of these 13 articles (76.9%), attributed to the work of Hodgson, promoting early and radical anterior debridement as the "gold standard" for spinal TB. China is listed both as a high-burden TB country with a high multidrug resistance TB and HIV-TB coinfection.[5]

On the other hand, only 4 publications (4%) originate from the continent of Africa, with 3 of them being conducted in South Africa: E. B. Hoffman et al; J. A. Louw and S. Govender; P. G. Konstam et al conducted their research in Nigeria.

Africa has one of the highest TB burden and highest TB-HIV coinfection rate worldwide[2,5] (Figure 2), yet there is a discrepancy between clinical experience and published research. This might point toward insufficient resources available to African institutions to conduct research or publish their experience.

Study Category, Area of Research, and Study Type

Most studies were retrospective studies (n = 70; 70%), with only 6 (6%) prospective studies, of which 4 were randomized controlled trials (4%).

This indicates that retrospective research is still seen as important evidence in global literature on spinal TB and is of value to conduct, and on the other hand, it shows that prospective research and randomized controlled trials are very scare and future research should fill this gap.

The most popular area of research was the clinical course of spinal TB (n = 30; 30%), focusing on the overall clinical picture of the disease, diagnosis, and treatment. The second most popular area was surgical technique (n = 26; 26%) followed by clinical outcome (n = 23; 23%) and imaging (n = 21; 21%). This shows that most centers in high-burden areas have no access to funding and extensive laboratory support to conduct basic science research or large randomized controlled trials.

Quality

Most studies were retrospective and therefore granted level IV evidence. This could be due to the fact most studies were conducted in resource restrained areas were little funding and equipment is available and randomized controlled trials are hard to set up. Indian researchers seem to be the most resourceful as 3 of the 4 prospective studies were conducted in India.

On the other hand, relatively simple studies are contributing to our knowledge on spinal TB, showing that centers with limited resources can contribute to the body of evidence without the need of major research resources.

Limitations

Bibliometric analysis provides an overview of literature at one specific time point. Due to the dynamic field in which academic literature is used, citation numbers change every day. For instance, the most recently published article is by R. K. Garg et al, published in 2011. It received 41 citations, was cited 12 times in 2014 and it has a citation rate of 8.2 per year.

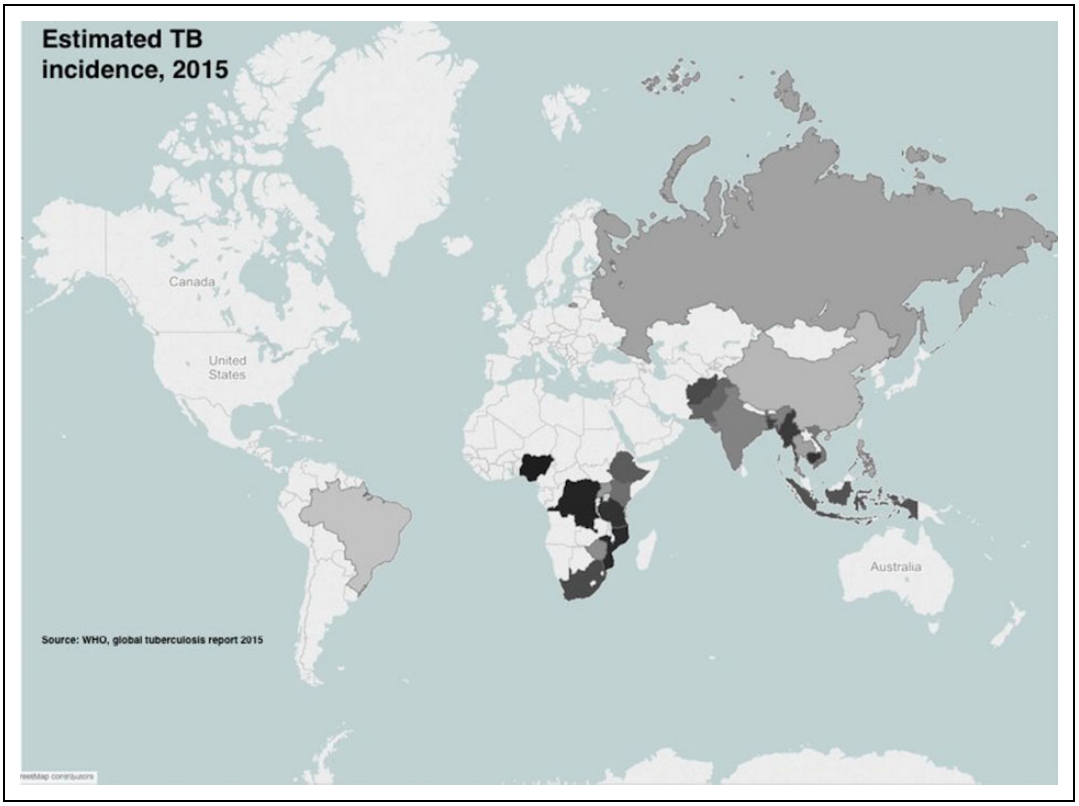

Figure 2. Estimated TB burden. Incidence of TB per country, as taken from the most recent WHO TB report. Countries are highlighted with light gray (lowest incidence) to dark gray (highest incidence).

Looking at the citation density and number of publications in 2014, this article is likely to climb into the top 100 most cited articles in the future. Therefore, it has the possibility to become more important in the current literature. This publication highlights the fact that we might need to focus on citation density and citations in recent years to keep up with the dynamic effects of younger but influential articles.

One problem of our study might be that it cannot answer the question, whether the low citation rate of countries with high disease burden is due a low productivity itself or due to a low citation rate per se. Future research could address this by assessing the global research output of these specific countries.

Article age is of importance in a bibliometric analysis; the older an article is the longer it can gather citations. P. G. Konstamp et al published their article in 1962 and it has been granted 104 citations since, making this the 20th article in our list. In 2014, the article did not receive new citations, which could question its significance in the current literature.

Conclusion

This bibliometric study provides the 100 most influential articles on spinal TB. Most studies focused on clinical outcome and were LoE IV. India contributed most articles, followed by the United States and China. Almost half of the articles in our selection originated from developed countries. Only 4 articles were produced from African centers. Our study serves to highlight the low impact of publications in the field of spinal TB from endemic areas, especially the African continent. There is a lack of prospective studies with a higher level of evidence. Collaborations of centers in low-income countries and high burden of disease with centers with high research output in countries with sufficient resources may be one solution to overcome this research gap.

Declaration of Conflicting Interests

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